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Monitoring of Vegetation Spatial Pattern, Diversity and Carbon Source/Sink Changes in Arid Grazing Ecosystem of Xinjiang, China by Ecological Survey and 3S Technology

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Abstract

Changes of land-use policy and herdsmen settlement in mid-1980s have significantly altered the diversity of vegetations in aid grazing ecosystems. To examine the spatial dynamics of vegetation species and the changes of carbon source/sink, ecological survey, accompanied with 3S technology, had been applied in this study. A total of 1169 vegetation samples were collected along two 5 km transects, along with topographic and demographic variables (slope, aspects, population, distance from the center of new herd farms). Analysis of this dataset revealed that more than 1/3 of the lands were in serious degradation with dominant unpalatable plant community. The increase in the abundance of inedible plant *Peganum harmala* in sunny slope near the farm and some annual unpalatable species in the lower land indicated serious degradation of grassland. The roads， the heavily used patches, impacted plant cover greatly, a decrease of 24.8% comparing to adjacent patches. This field experiment demonstrated that there were significant relationships between plant cover and two driving factors; slope degree and distances from the new farm center; on the other side, the results of spatial data analysis provided basis for improving the grassland carbon balance condition. In general, plant cover declined with increases in slope and decreases in the distance.

Keywords: plant cover, grazing, 3S technology, carbon source/sink, Ecological formation

1. Introduction

In arid and semi-arid regions, human activities are increasingly altering the natural ecosystems, for food and other resources exploitation, and impact the spatial dynamics of vegetation, especially their species composition [1]. Some researchers showed that interactions among the multi-scale factors such as climate and geomorphology caused distinct spatial patterns of vegetation composition [2]. Aguado-Santacruz et al. [3] examined the spatial heterogeneity of vegetation species over an arid region in the central Mexico and found that an aggregate of many driving forces resulted in grassland degradation. In

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related to the Tianshan mountains region, more and more grasslands have been seriously degraded by intensive disturbance of human activity due to the change of land use policy and herdsmen settlement. Some of the lands close to the new farms in the region were in extreme degradation. By analyzing the plant community spatial distribution, previous researchers have sought to quantify the degree of degradation of natural vegetation communities [4].

On the other side, with the development of 3S technology, remote sensing technology was introduced into the estimate of carbon change monitoring. Based on the analysis of various global ecosystem carbon sink estimation methods and the original research achievements, the carbon source/sink change of the main grassland in China is studied using the "3S" technology, which is suitable for grassland in China.

The objectives of this paper are to evaluate the spatial change of vegetation species on the northern slope of the Tianshan Mountains, and to identify the relationship between human disturbances (grazing intensity, distance to human settlement, road and gully patch) and spatial patterns of vegetation composition.

2. Materials and methods

2.1. Study area

The study area, Shuimogou village, is located in a lower mountain belt on the northern side of the Tianshan Mountains, under the Bogda peak, in Xinjiang Uygur Autonomous Region, China (Fig. 1). This area is approximately 20 km south of Fukang city, 60 km east of Urumqi city and 80 km northeast to the geographic center of the Asian continent. The study area is characterized by a gentle slope between two major steams leading to the peak Bogda [5]. Botanically, the area has strong floristic affinity to the central Asia geographic region that stretches from western Asia through the Tianshan Mountains to western Mongolia. The study area is in a typical region of the arid ecosystems in the Tianshan Mountains, with a complex mosaic of streams and mountain ridges running down the top of the Tianshan Mountains. The main geomorphic forms within the study area are loess in the typical arid climate. The study area is grazed primarily in the spring and fall each year. The elevation of the study area ranges between 700 m and 1100 m [6]. The meteorological data were obtained from the only station nearby Fukang city (at an elevation of 520 m), about 20 km away from the study area.

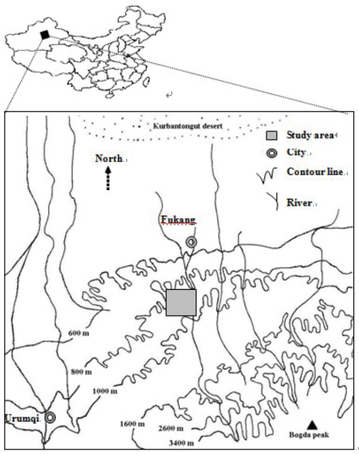

Fig.1 The location of study area in Xinjiang Uygur Autonomous Region of China.

The study area as a whole was characterized by sparse plants dominated by subshrub *Seriphidium borotalense* (Poljak.) Ling & Y.R. Ling, with the plant cover of 5-30%. This subshrub is generally the dominant native species in some semi-shrubby desert, and extensively distributed in arid regions, especially on the northern slopes of the Tianshan Mountains [7]. Most of them play a prominent role in animal nutrition for heads and flocks in spring and autumn. The *Seriphidium* shrubs, like the *Artemisia* desert, are an important palatable species with high feeding value in spring and autumn. The common companion species in the area are *Salsola dshungarica* Iljin, *Chenopodium glaucum* L., *Ceratocarpus arenarius* L., *Stipa caucasica* Schmalh. subsp. *desertorum* (Roshev.) Tzvelev*, Carex liparocarpos* Gaudin.

2.2 Experimental design

Considering that the river and gully stream flow from the south of high mountain to the north of sandy desert, two transects with the latitudes of 44°00.610′ and 44°01.610′ (directed by GPS 315 and a compass) were laid out within the study area to collect vegetation samples in the lower mountain belts. These two transects, cross the Shuimogou river perpendicularly, cut across geographic features including roads including lanes and footpaths (the lane was used for vehicle transportation for herdsmen living and seasonal transition to other pastures, and footpath was used by livestock,), gullies (small gullies), sheepfolds (the center of the farm), property boundaries, and individual cottages, beginning from the Shuimogou river to the gully of Big Honggou stream.

In this study, 3S technology was a integrating monitor method of grassland dynamic condition, and use ERDAS to deal with remote sensing image and information extraction, then estimate the productivity, yield and Carbon payments of grassland in experimental field.

The grassland carbon storage ability is estimated as follows:

$$CR_i = S_i \times CD_i \quad (1)$$

Where the CR_i is the carbon storage of i type grassland vegetation, S_i is the distribution area of i type grassland vegetation(hm^2), CD_i is the organic carbon density of i type grassland vegetation (kg/hm^2).

$$CDi = Yi \times Ci \quad (2)$$

Where Y_i is the biomass of i type grassland vegetation, C_i is the organic carbon content of i type grassland vegetation (kg/hm^2).

2.4. Data analysis

The SPSS package was used to analyze the spatial distribution of vegetation species as a function of environmental variables including slope, road, gully, and the distance from homesteads. In this study, plant covers were dependent variables while all other landform including slope aspect, degrees of the slope, road, gully, and sheepfold were independent variables.

3. Results

3.1 Spatial pattern of vegetation species and feeding values

Spatial distributions of plant species largely depended on the spatial variations of environmental conditions. Widespread and dominant species in all sites were *Seriphidium borotalense* (Borotal Seriphidium or Borotal wormwood). It occurred in 792 sampling quadrates, 67.8% of the total 1169 sampling plots. This species was favorable foliage for livestock in cold season such as spring and autumn but it is unfavorable in summer because of the bitter taste in the plant. Total palatable species occurred mostly (1004 of all plots) within the cover range of 0-30%. Only a few parts (111 of all plots) comprised more than 30% of the covers, and they occurred 22 in shady slope (47.8% of total shady slope). The sunny slopes had few plant species. Some drought tolerant species such as *Artemisia xerophytica* Krasch. and *Ceratoides latens* (J. F. Gmel.) Reveal et Holmgren, *Reaumuria soongorica* Maxim.*, Caragana soongorica* Grubov *were* distributed in upper sunny sites. Lower land had more plant species than other adjacent slopes. The unpalatable and inedible plants were found in 621 plots, 53.1% of total sampling plots were mainly distributed in lower land with gentle slopes.

3.2. Temporary change of vegetation species

In the most recent twenty years, the grassland has experienced a great change after many years of serious overgrazing. Both the production and quality of the vegetation (including the diversity of palatable plants) have fallen greatly considering an increase (8.8%) of the precipitation in 2004 (**Table 1**). This investigation showed that the palatable species such as *Kochia prostrata* occurred infrequently (rare species), while inedible plants such as *Peganum harmala* and some species of *Chenopodium* occurred frequently. These changes indicated that the community of vegetation species altering from more palatable species to absolutely dominated species Seriphidium communities, then to ones containing more annual inedible species with little economic function.

Table 1 The change in vegetation characteristics from 1982 to 2004

Year	Species distribution	Mean cover (%)	Mean height (cm)	Production (kg DM/ha)	Precipitation (mm)
1982	The dominant species was *S. borotalense,* companion species were *Stipa caucasica, Kochia prostrata,* some species such as *Petrosimonia sibirica, Salsola dshungarica* occurred in lower land, and *Ceratocarpus arenarius* occurred in upper sites of slopes	30.0 (range from 15.0 to 45.0)	30.0 (range from 18.0 to 42.0)	1032.3 (determined in typical sampling plot)	184.7
2004	The dominant species was *S. borotalense*, companion species included *Salsola dshungarica, Chenopodium glaucum, Ceratocarpus arenarius, Petrosimonia sibirica, Suaeda dendroides, Stipa caucasica*, etc. *Kochia prostrata* became rare species. *Peganum harmala* increased	19.3 ±12.7(std.) (1179 sampling plot)	23.9 ±2.8(std.) (8 sampling plot)	647.0 ±86.03(std.) (determined in 5 sampling plot)	200.9
Increase		-35.6%	-20.3%	-37.3%	+8.8%

3.3. Relation between vegetation and distance to the new farm

The results of two variable regression analysis, by regression analysis of the dependant variables (plant cover and density) and independent variables (slope, the distance to farm center) in partially sunny slope, in 1040 data of partially sunny slope confirmed that there was a significant relationship between plant variable (palatable species cover, total plant cover) and two independent variables (slope degree and distance to farm center) (P <0.05). The regression coefficient tests showed that there were significant regression relationships in every coefficient of the two equations (**Table 2**).

$$\overline{y_1} = 15.341 + 0.00192D - 0.187S$$

$$\overline{y_2} = 22.458 + 0.00238D - 0.143S$$

where, $\overline{y_1}$, $\overline{y_2}$ is vegetation cover (%) of total palatable species and total plants, respectively; D is the distance to farm center, and S is the degree of the slope, given the variables of the distance and slope, the plant cover can be estimated using these equations. Generally, plant cover declines with increases in slope and decreases in the distance.

Table 2 Coefficients in multiple regression equation (Enter)

Pant cover	Model	Unstandardized Coefficients		t	Sig.
		B	Std. Error		
Palatable plant cover	Constant	15.011	0.929	16.166	0.000**
	Slope	-0.151	0.023	-6.684	0.000**
	Distance	0.002	0.001	3.175	0.002**
Total plant cover	Constant	22.244	1.059	20.997	0.000**
	Slope	-0.107	0.026	-4.143	0.000**
	Distance	0.003	0.001	3.025	0.003**

** The mean difference is significant at the 0.01 level.

3.4 Prospects of landscape analysis in keeping carbon balance in grassland

Conbined with various ecological survey results, the analysis of remote sensing data such as MODIS, and then estimate NPP LAI of the experimental area. These results will do great effects on monitoring grassland conditions changes and determine the primary productivity changing of grassland, and also provided basis for improving the grassland carbon balance condition.

4. Conclusions

Due to the change of land-use policy in mid-1980s, herdsmen settlement and the increase of livestock population has imposed a significant impact on diversity of vegetations in aid grazing ecosystems. More than 1/3 of the lands were in serious degradation with dominant unpalatable plant community. The increase in the abundance of inedible plant *Peganum harmala* in sunny slope near the farm and some annual unpalatable species of *Salsola, Chenopodium* in the lower land indicated serious degradation of grassland.

The unequal distribution of plants in grazing ecosystems occurred because of different attributed pattern of the landform, sheepfold, road, gully, and as well as grazing. The correlation of plant characteristic value with slope degree indicated the basic spatial distributed trend in degraded hill land with short slope sites. The roads and some small gullies， the heavily used patches, affected plant cover greatly at the overgrazing land.

There were significant relationships between plant variables and two driving factors; slope degree and the distance from the new farm center. In general, plant cover declined with increases in slope and decreases in the distance of grazing.

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